

WHAT IS CLAIMED IS:

1. A centrifugal fluid pump apparatus comprising a pump body in which an impeller rotates without contacting a housing; and a control mechanism for said pump body,

5 said pump body including:

said housing having a blood inlet port and a blood outlet port;

a centrifugal pump section including an impeller having a first magnetic material and a second magnetic material and rotating in said housing to feed a fluid by a centrifugal force generated during its rotation;

10 an impeller rotational torque generation section including a rotor having a magnet for attracting said first magnetic material of said impeller and a motor for rotating said rotor;

15 an impeller position control section having an electromagnet for attracting said second magnetic material of said impeller;

a position sensor for detecting a position of said impeller; and

20 hydrodynamic bearing means provided on an inner surface of said housing at a side of said rotor or on a surface of said impeller at a side of said rotor,

said control mechanism comprising:

25 a position sensor output monitoring function or an electromagnet current monitoring function;

a motor current monitoring function;

a failure detection function for determining a failure of the sensor by using said position sensor output monitoring function or a failure of the electromagnet by using said electromagnet current monitoring function; and

30 an emergency impeller rotation function operating when said failure detection function detects the failure of the sensor or the failure of the electromagnet to rotate said impeller by utilizing said hydrodynamic bearing means without substantial contact between said impeller and said housing,

wherein said emergency impeller rotation function has:

30 rotation termination function of terminating power to the motor and the electromagnet when the failure detection function detects a failure to thereby terminate rotation of the rotor and the impeller;

35 impeller magnetic counterforce application function to apply a current to the electromagnet sufficient to overcome the magnetic coupling force of the rotor to the impeller caused by the magnet;

40 hydrodynamic levitation control detection function of detecting hydraulic bearing coupling and thereby magnetic rotational coupling of the impeller and the rotor under hydraulic bearing conditions by using a motor current monitored by the motor current monitoring function;

45 motor speed control function for increasing the motor speed and hence the impeller rotation speed up to a predetermined value after the hydrodynamic levitation control detection function detects that the hydraulic bearing coupling between the impeller and the rotor has been made; and

50 impeller magnetic counterforce termination function to terminate current to the electromagnet once the predetermined impeller rotation speed is reached.

2. A centrifugal fluid pump apparatus according to claim 1, wherein said control mechanism has said position sensor output monitoring function and said electromagnet current monitoring function and said failure detection function can determine the failure of the sensor and the failure of the electromagnet.

3. A centrifugal fluid pump apparatus according to claim 1, further comprising a sensor circuit for said sensor, wherein said sensor circuit has a function of generating an output having a predetermined value exceeding a normal level when said sensor has disconnection, and said failure detection function determines whether said sensor has a failure, based on an output of said sensor monitored by said sensor output monitoring function.

4. A centrifugal fluid pump apparatus according to claim 1, further comprising an electromagnet circuit for said electromagnet, wherein said electromagnet circuit is not energized when said electromagnet has disconnection, and said failure detection function determines that said electromagnet has a failure when said electromagnet current monitoring function monitors that electric current is not applied to said electromagnet circuit.  
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5. A centrifugal fluid pump apparatus according to claim 1, wherein when said failure detection function detects a failure, said emergency impeller rotation function allows said impeller to rotate by balancing the magnetic coupling force between the magnet of said rotor and said impeller and the counterforce generated by said electromagnet..  
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6. A centrifugal fluid pump apparatus according to claim 1, wherein said hydrodynamic bearing means includes at least one groove provided on the inner surface of said housing at a side of said rotor.
7. A centrifugal fluid pump apparatus according to claim 1, wherein said hydrodynamic bearing means includes at least one groove provided on the surface of said impeller at a side of said rotor.
8. A centrifugal fluid pump apparatus according to claim 1, wherein said hydrodynamic bearing means includes a plurality of steps provided on the surface of said impeller at a side of said rotor.
9. A centrifugal fluid pump apparatus according to claim 1, wherein said impeller magnetic counterforce application function comprises applying a first duration current to the electromagnet to create a counterforce and attempting to rotate the impeller by applying a predetermined voltage to the motor.

10. A centrifugal fluid pump apparatus according to claim 9, wherein when the motor fails to achieve rotation of the impeller after the first attempt, said impeller magnetic counterforce application function further comprises applying a second duration current to the electromagnet to create the counterforce and attempting to rotate the impeller by applying the predetermined voltage to the motor, wherein said second duration current is greater than said first duration current such that the counterforce created with said second duration current is greater than the counterforce created with said first duration current.

11. A centrifugal fluid pump apparatus according to claim 10, wherein said second duration current is greater than said first duration current by a predetermined step value.

12. A centrifugal fluid pump apparatus according to claim 11, wherein when the motor fails to achieve rotation of the impeller after the first and second attempts, said impeller magnetic counterforce application function further comprises repeatedly applying an increased duration current to the electromagnet to create the counterforce and attempting to rotate the impeller by applying the predetermined voltage to the motor, said increased duration current being repeatedly increased by the predetermined step value until one of rotation of the impeller is achieved or said increased duration current reaches a predetermined maximum value.

13. A centrifugal fluid pump apparatus according to claim 12, wherein said first duration current is a 10% on time duty cycle.

14. A centrifugal fluid pump apparatus according to claim 12, wherein the predetermined step value is 1%.

15. A centrifugal fluid pump apparatus according to claim 12, wherein the predetermined maximum value of said increased duration current is approximately 20% on time.